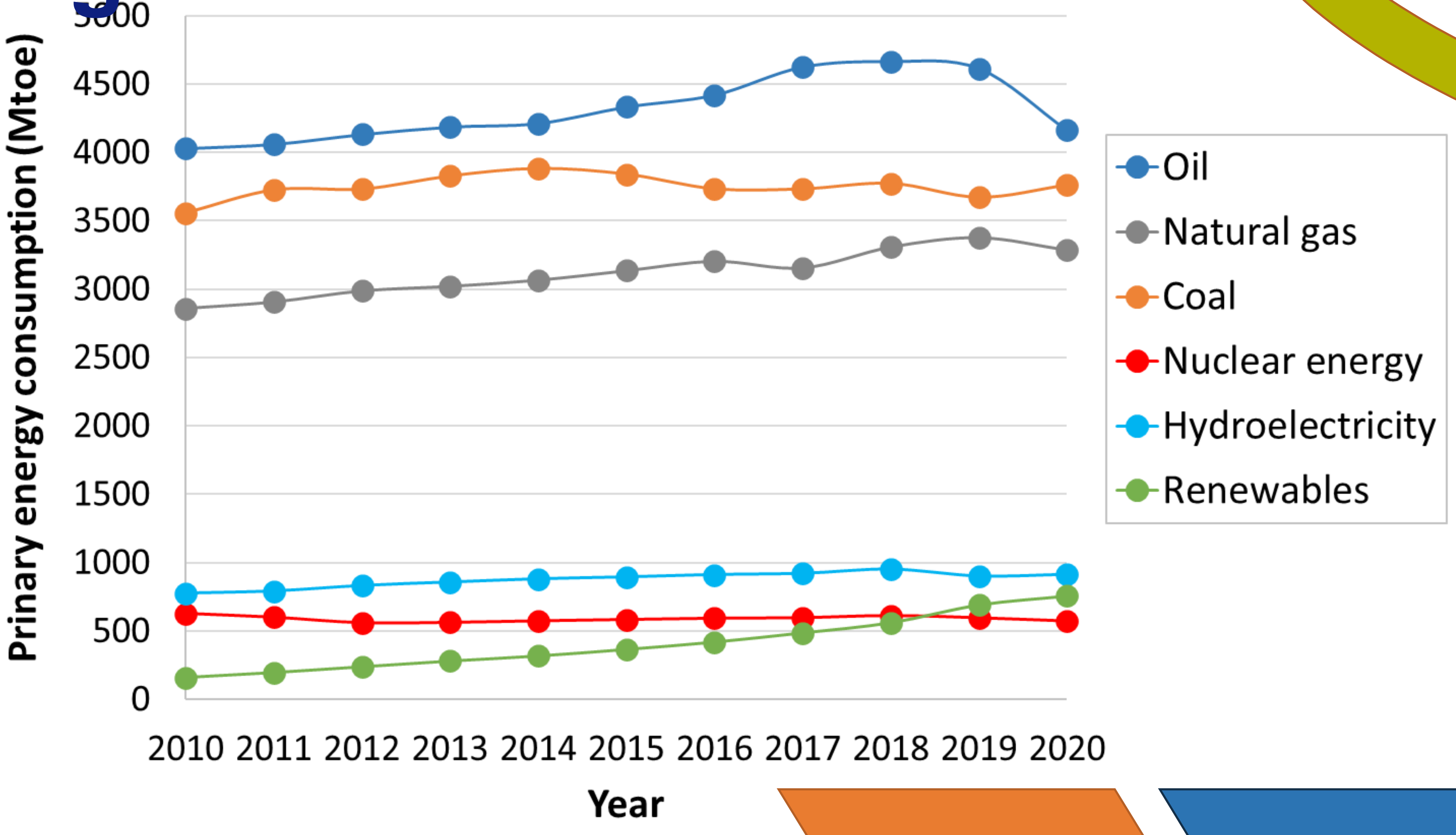
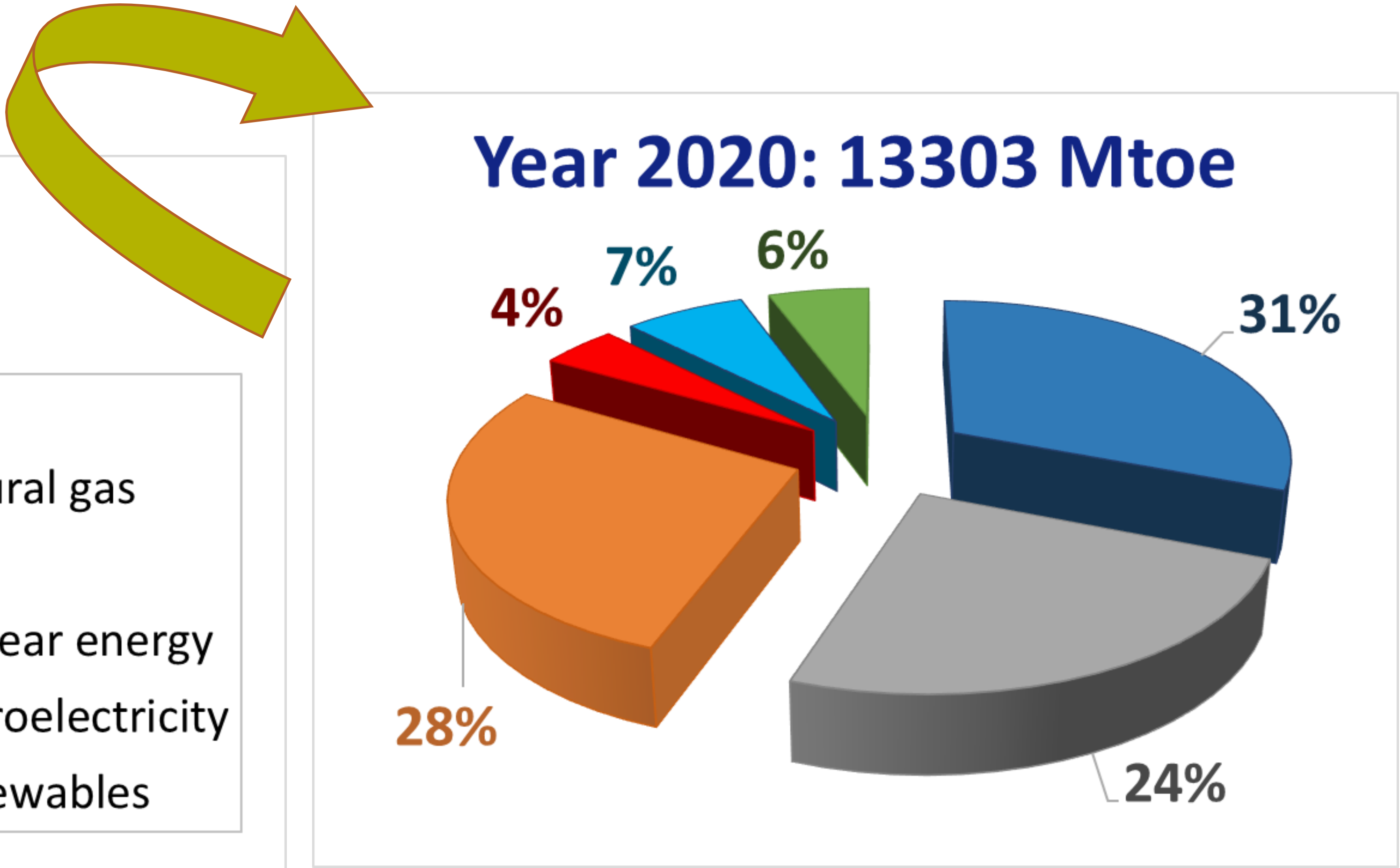
Optimization model for the extraction of lipids from urban sewage sludge

Luigi di Bitonto, Enrico Scelsi, Carlo Pastore

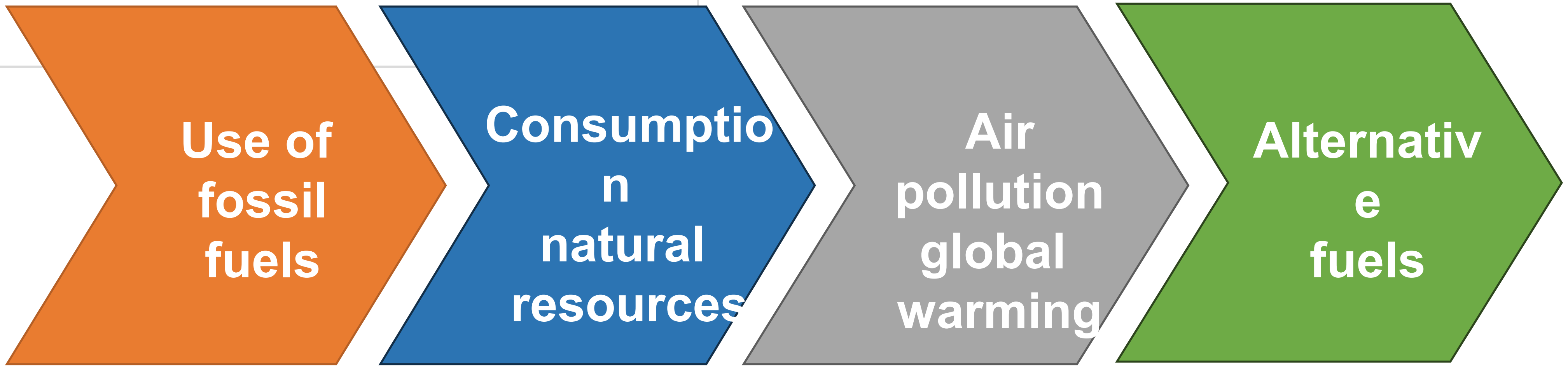
Enviromental problem targeted



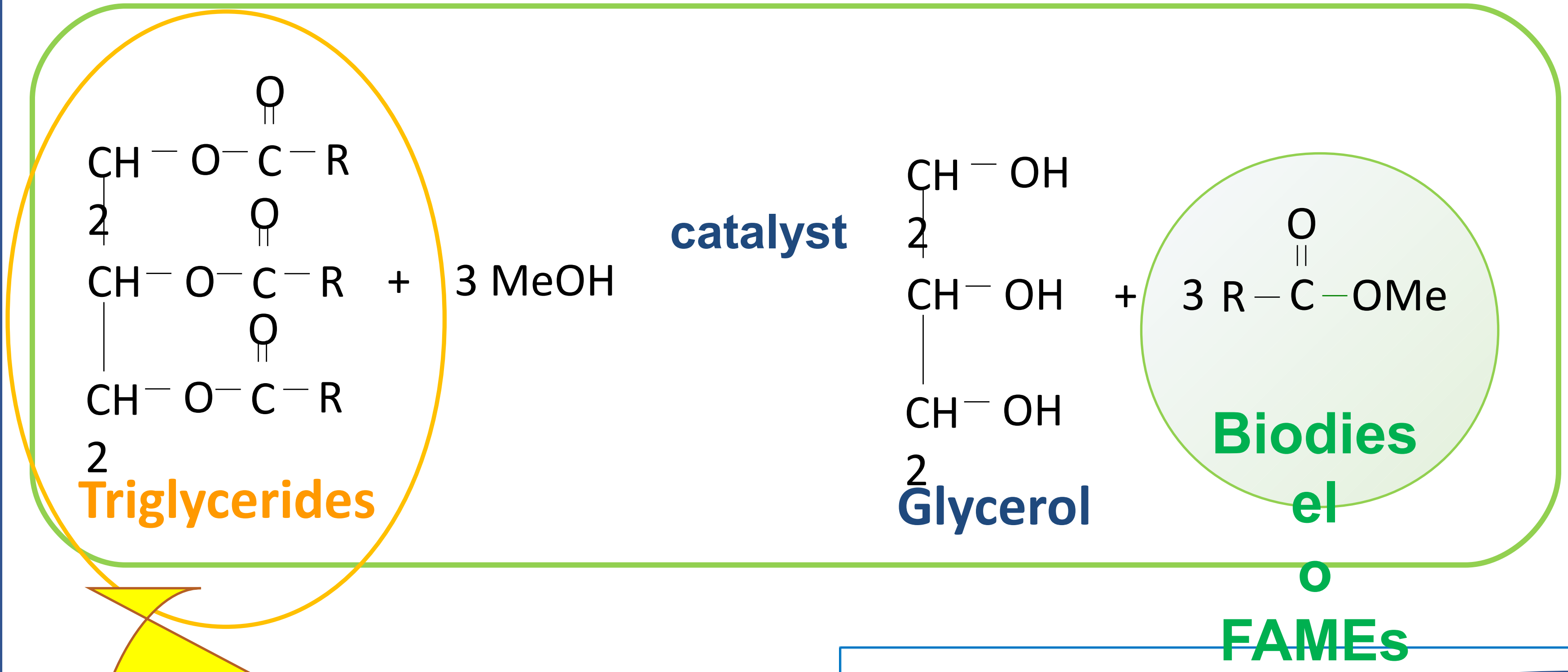


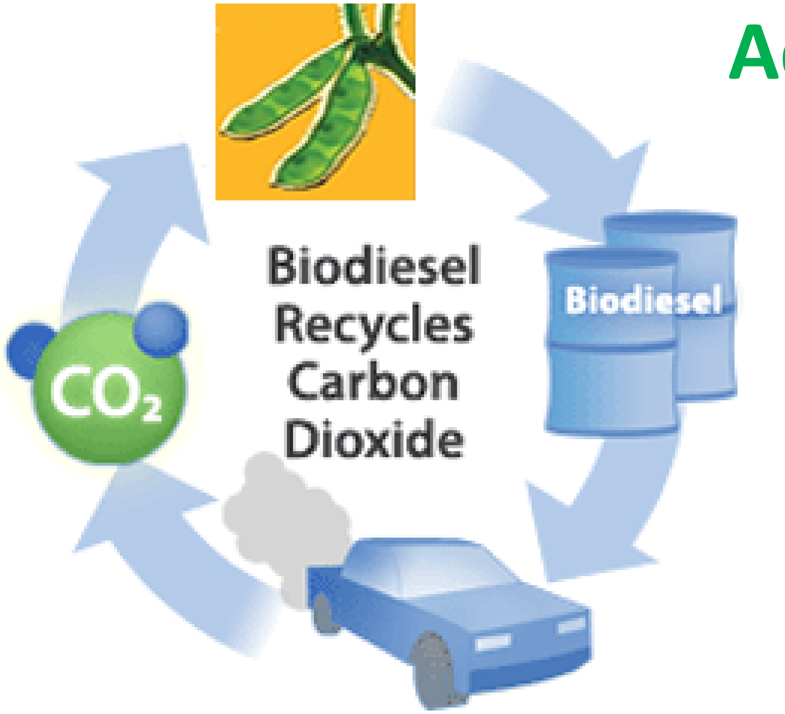
BP Statistical Review of World Energy 2021

Figure 1. Evolution of the petroleum production worldwide



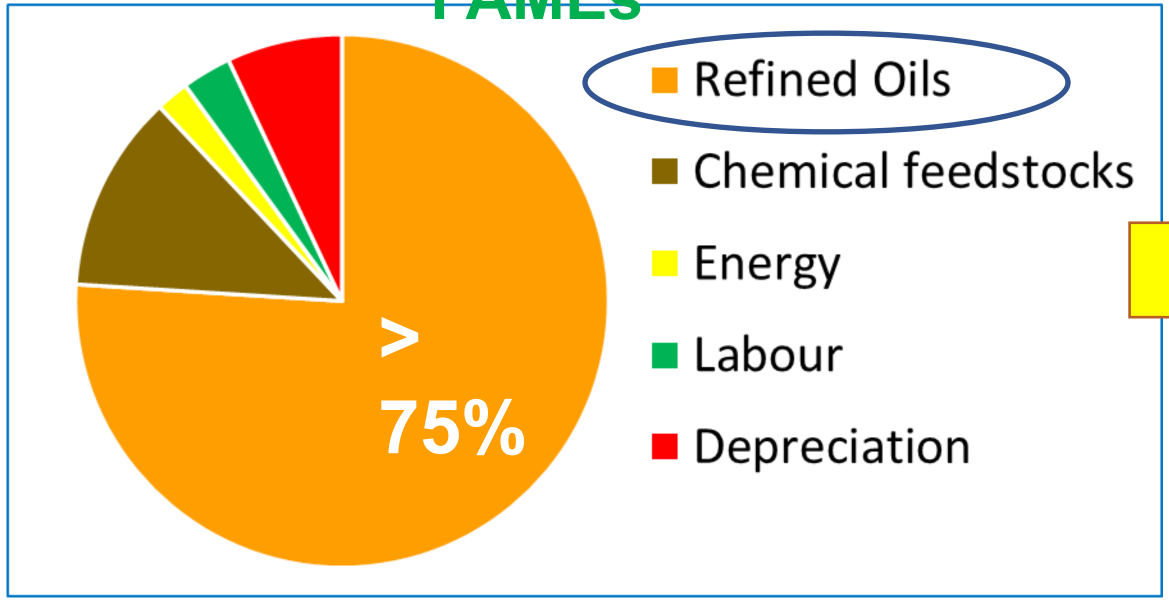
Biodiesel





Advantages

- Availability
- Biodegradability
- No Toxic emissions SOX, NOX

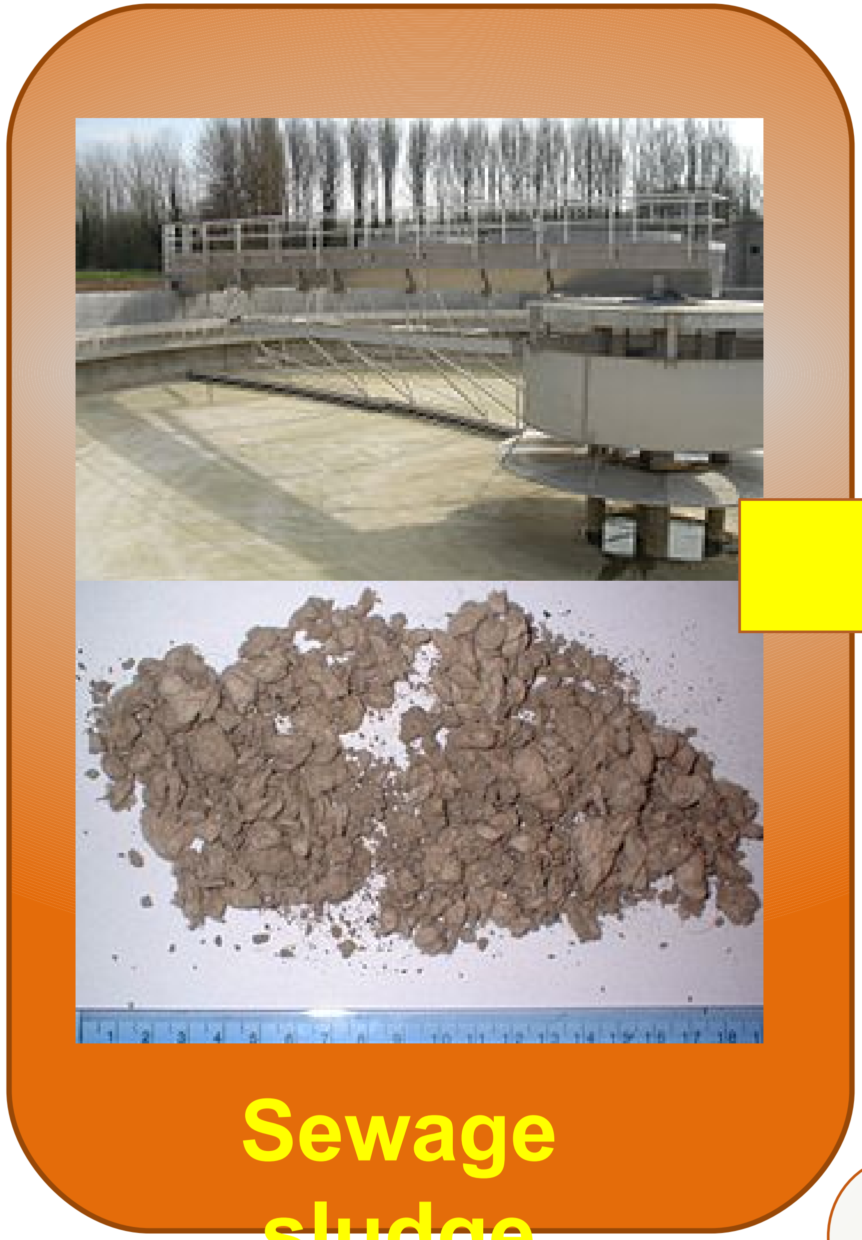


Refined oils

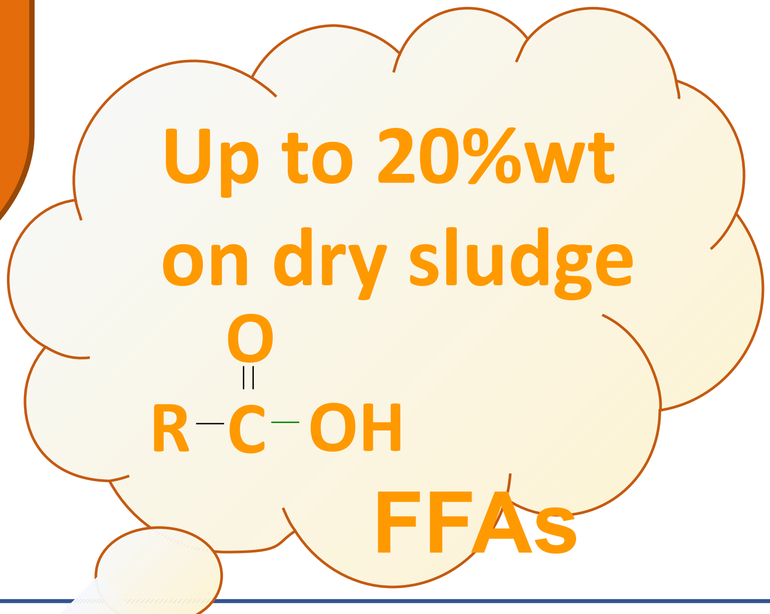
Evaluation costs

Cheaper feedstocks

Urban sewage sludge



Lipids



European sewage sludge production

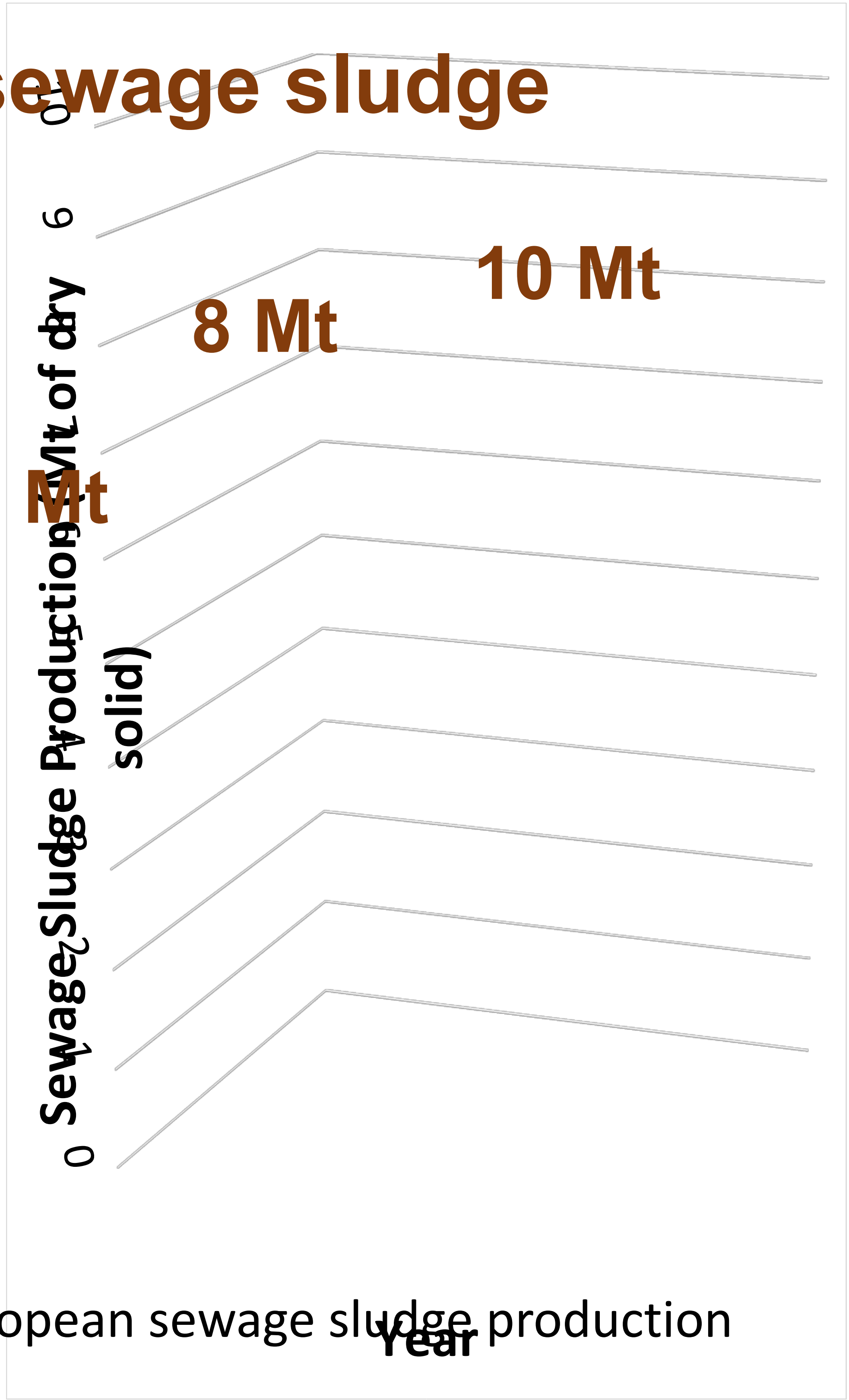


Figure 2. European sewage sludge production

Catalysts 11 (2021) 663

Lipid extraction from sewage sludge

CONVENTIONAL PROCESS

Main drawback = water content (95-98% of sewage sludge)

DRAWBACKS

- Reagents cost
- High energy required for lipid extraction
- Part of solvent remained entrapped into the EXHAUSTED SLUDGE (8-10%wt)

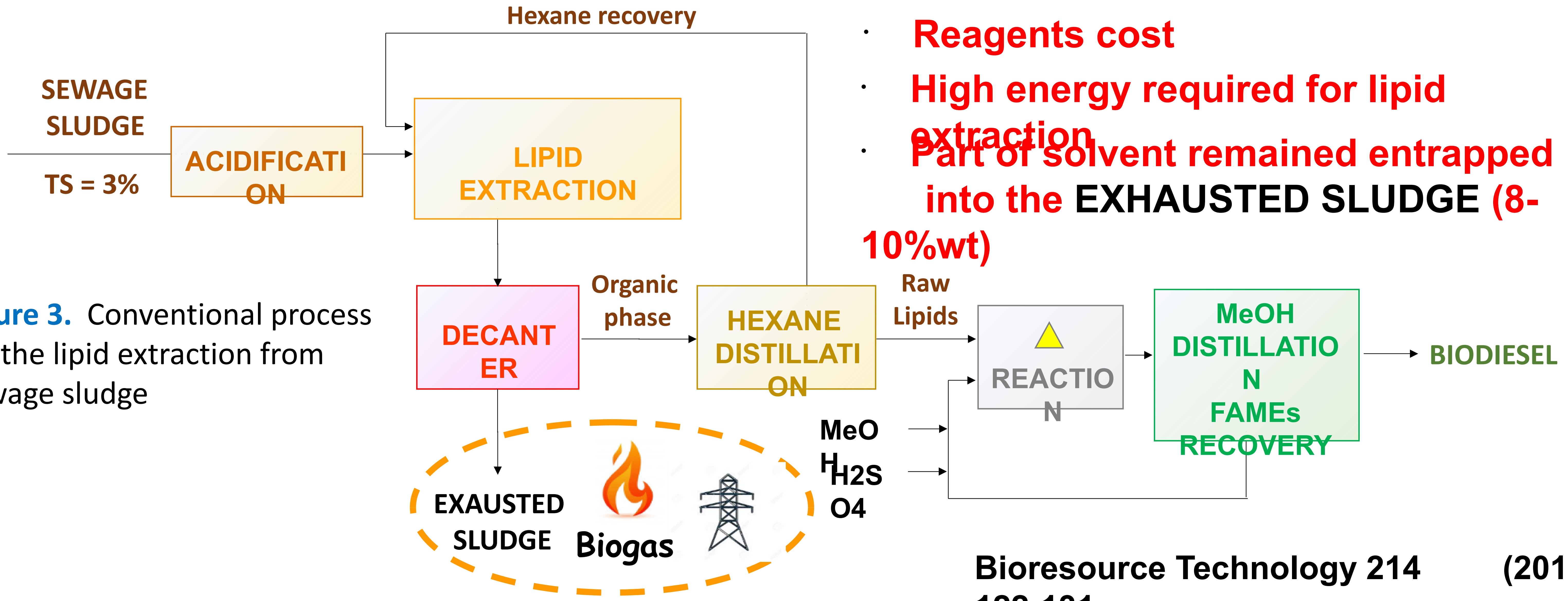


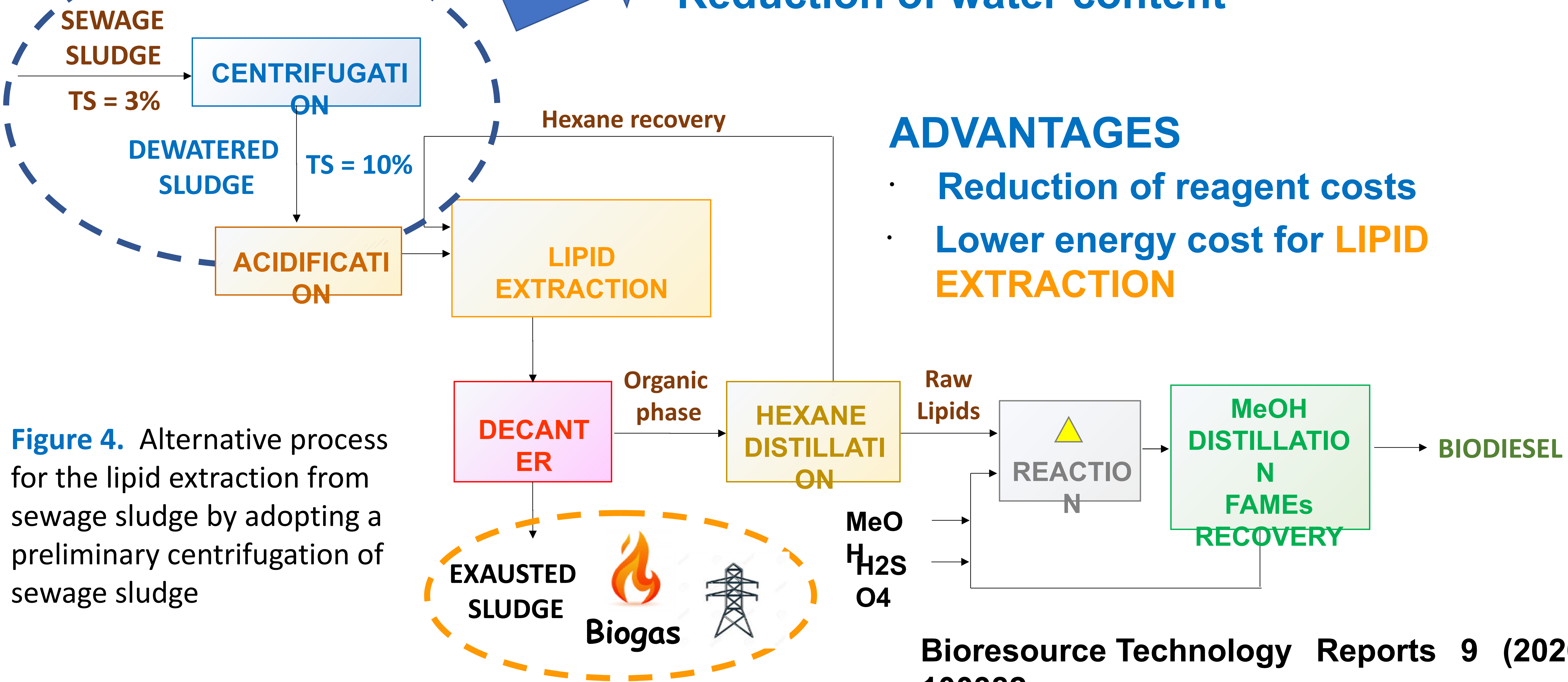
Figure 3. Conventional process for the lipid extraction from sewage sludge

Bioresource Technology 214 (2016) 122-131

Aim of work

PROPOSED PROCESS

PRELIMINARY CENTRIFUGATION: Reduction of water content



ADVANTAGES

- Reduction of reagent costs
- Lower energy cost for LIPID EXTRACTION

Figure 4. Alternative process for the lipid extraction from sewage sludge by adopting a preliminary centrifugation of sewage sludge

Bioresource Technology Reports 9 (2020) 100382

Aim of work

Economic evaluation: Aspen Plus® V.9

CONVENTIONAL VS PROPOSED PROCESS

Plant capacities:

- **500.000 PE (100 ton h-1)**
- **200.000 PE (40 ton h-1)**
- **50.000 PE (10 ton h-1)**

Primary sludge composition	
Total solids (TS)	**(%wt)**
Starting (sedimented) sludge	3
After centrifugation	10
TS composition mg/gTS	
Saponifiable lipids	180
Waxes	20
Proteins	250
Cellulose	350
Ashes	200

Figure 5. Chemical composition of Primary Sludge uptaken from the WWTP of Putignano

Process simulation

Peng-Robinson equation of state

Table 1. FAs profile of lipids extracted from Primary Sludge

Fatty Acids (FAs) profile	
Lauric (C12:0)	1.3
Myristic (C14:0)	6.0
Palmitoleic (C16:1)	1.1
Palmitic (C16:0)	**50.2**
Oleic + Linoleic (C18:1+C18:2)	18.0
Stearic (C18:0)	16.7
Ketostearic (C18=0)	0.8
Hydroxystearic (C18:0H)	4.9
Docosanoic (C20:0)	0.4
AMW (g/mole)	**266.0**

PRIMARY SLUDGE

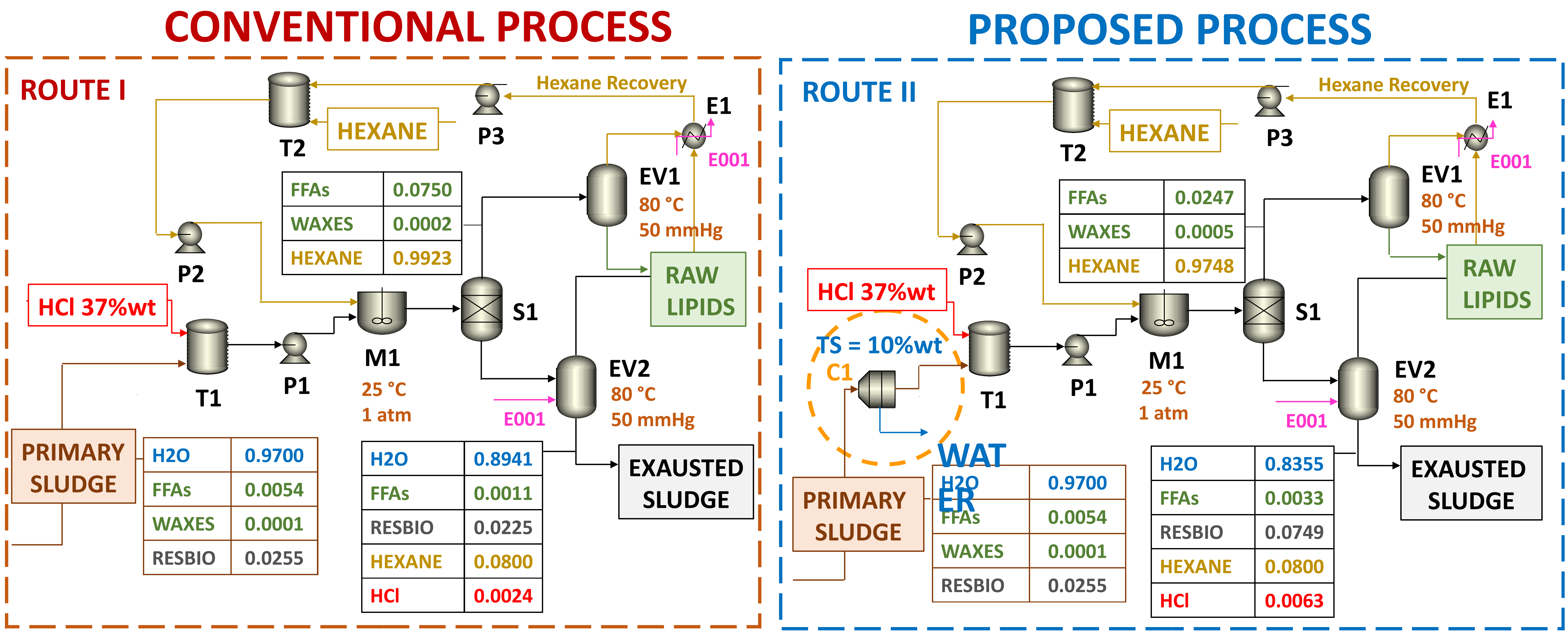
- **Total solids = 3%wt**
- **Lipid composition = 18% wtTS FFAs**
  = 2% wtTS Waxes
  (cetyl palmitate)

LIPID EXTRACTION CONDITIONS

- **Hydrochloric acid (HCl 37%wt)**
- **Primary sludge to hexane = 1:1 v/v**
- **Extraction Efficiency = 80%**

Applied Catalysis A: General 501 (2015) 48-55

Optimization model for the lipid extraction



C1 = centrifuge; M1 = reactor, T1, T2 = tanks and mixing systems; P1, P2 = pumps; S1 = separator; EV1, EV2 = evaporators

Figure 6. Simulation of conventional and alterative processes for the extraction of lipid component from primary sludge

Optimization model for the lipid extraction

Table 2. Determination of Total capital investiment CTCI for lipid recovery from Primary sludge by using conventional and alternative process.

Capital costs ($)	500000 PE (100 ton h-1)	
	CONVENTIONAL PROCESS	PROPOSED PROCESS
Centrifuge	-	230000
Tanks and mixing systems	704000	524600
Reactors	1048400	796100
Separators and evaporators systems	648600	455400
Heat exchangers	737000	300000
Pumps	215800	142000
Total bare module cost (CMC)	**3353800**	**2448100**
Contingencies and fees	603684	440658
Auxiliary facilities	1187245	866627
Total fixed capital costs (CFC)	**5144729**	**3755385**
Working capital (CWC)	**771709**	**563308**
Total capital investiment (CTCI)	**5916439**	**4318693**

Optimization model for the lipid extraction

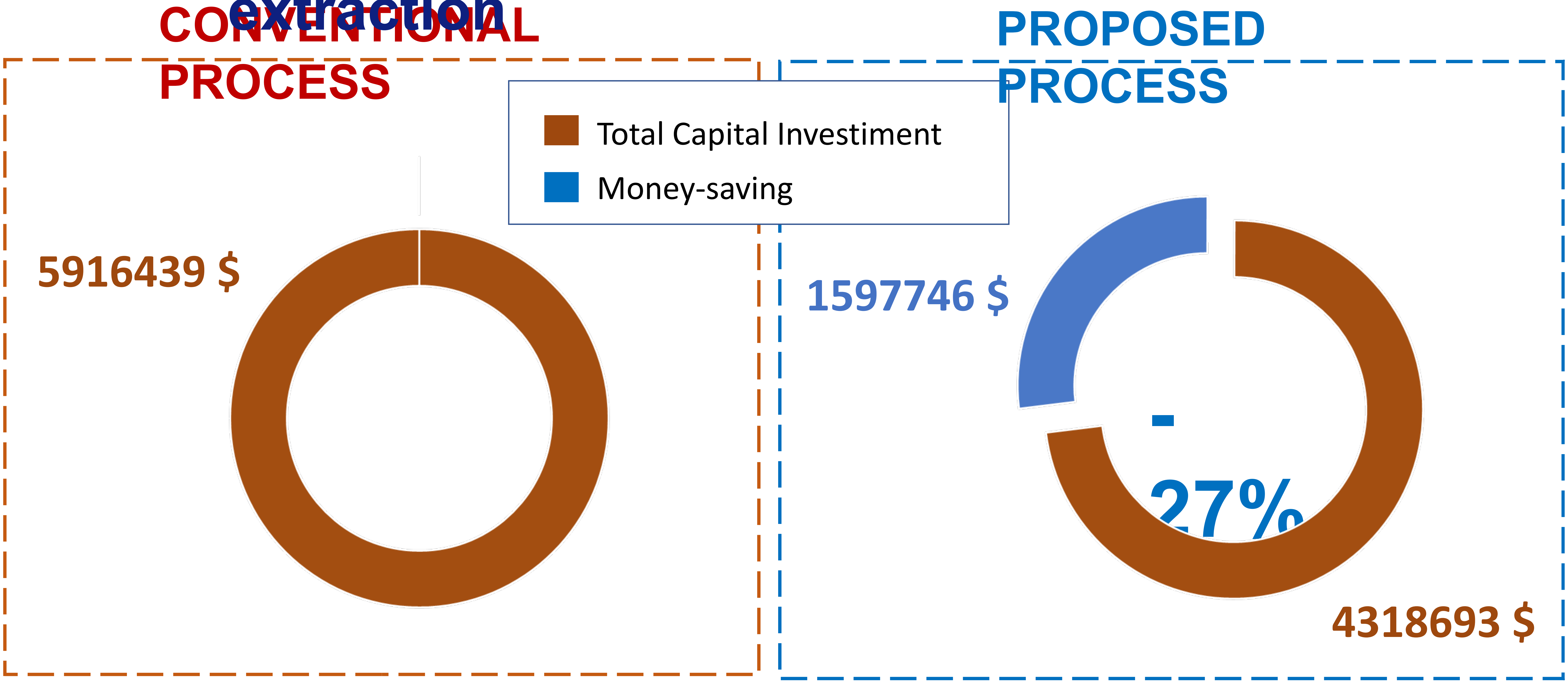


Figure 7. Comparison of Total Capital Investiment for both processes

Optimization model for the lipid extraction

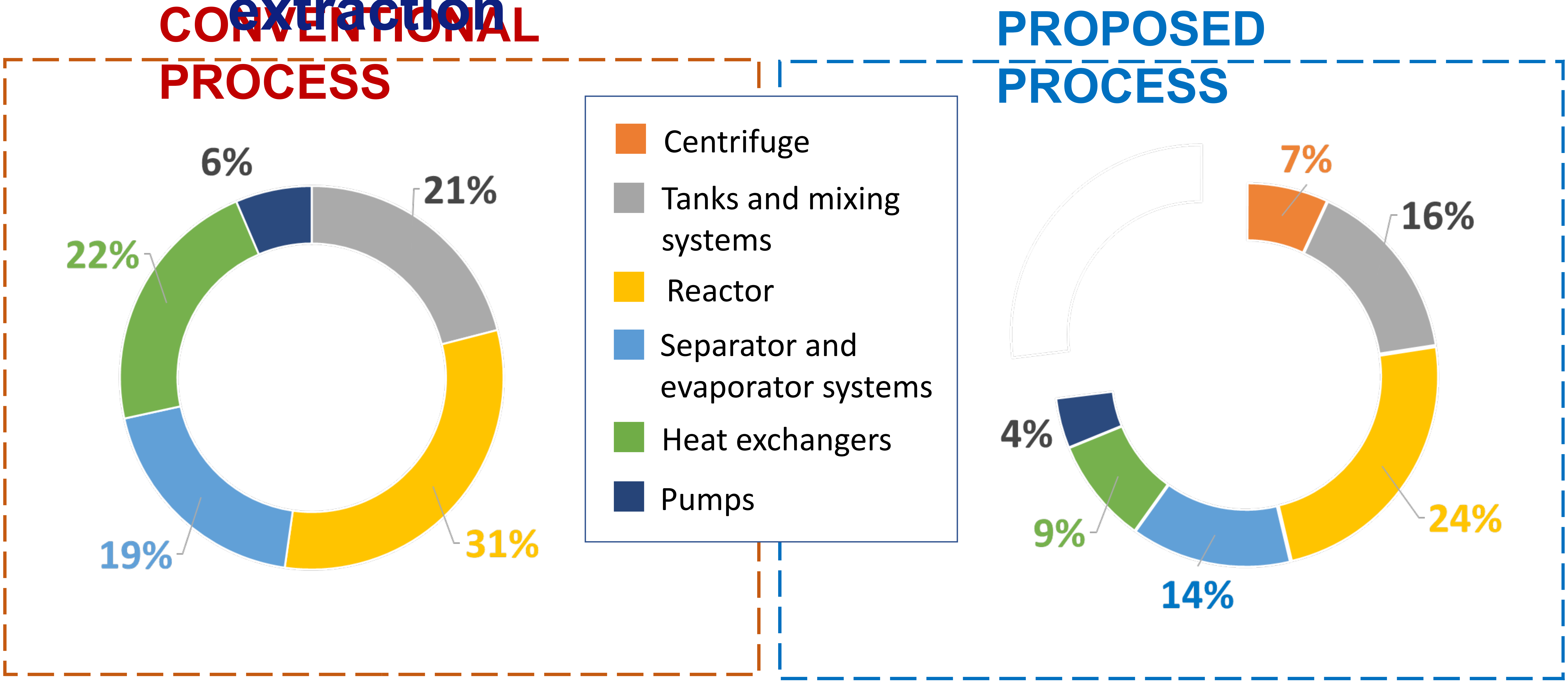


Figure 8. Total bare module cost for CONVENTIONAL and PROPOSED process

Optimization model for the lipid extraction

Table 3. Determination of Total Manufacturing Costs (CTM)

Item	500000 PE (100 ton h-1)	
	CONVENTIONAL PROCESS	**PROPOSED PROCESS**
Total capital investiment (CTCI)	5916439	4318693
Raw materials (CRM)	3192144	1236119
Utilities (CU)	368900	234293
Operating labour (COL)	134082	134082
Total manufacturing costs (CTM)	**6544724 $ year-1**	**3487533 $ year-1**

CTM = 0.304 CTCI + 2.73 COL + 1.23 (CRM + CWT + CU)

CWT = Waste treatment costs

Biogas production

Bioresource Technology 214 (2016) 122-131
Fuel 111 (2013) 535-542

Optimization model for the lipid extraction

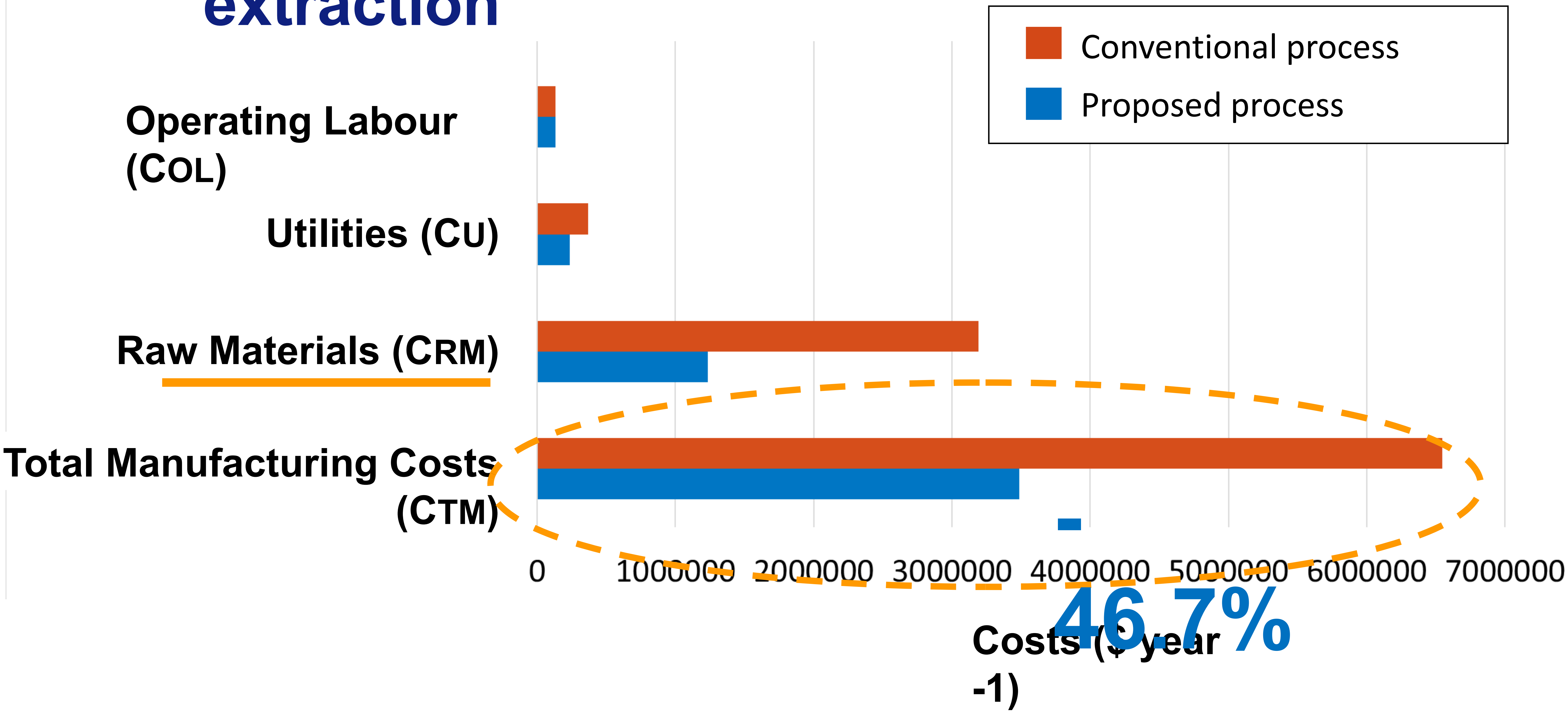


Figure 9. Determination of Total Manufacturing Costs (CTM)

Optimization model for the lipid extraction

Conventional process

Proposed process

$$BEP = \frac{\text{Total manufacturing costs } (C_{TM})}{\text{Total lipids extracted}}$$

1729 $ ton-1

vs

922 $ ton-1

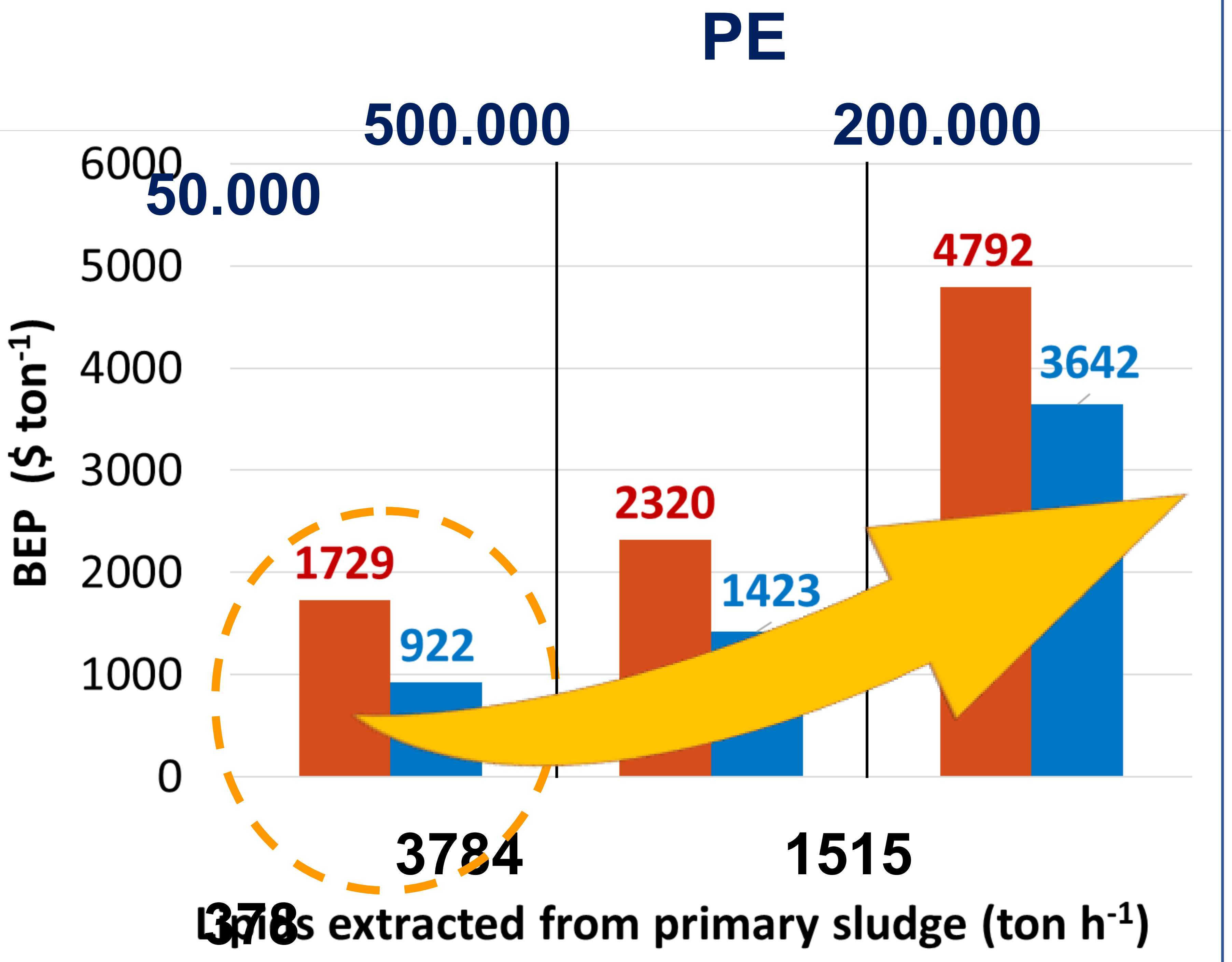


Figure 10. Profitability analysis for lipid extraction

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URBAN SEWAGE VALORIZATION TO BIODIESEL PRODUCTION: LIPID EXTRACTION THROUGH ADSORPTION ON SPUN NWOVEN POLY

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BIOLUBRICANTS FROM URBAN SEWAGE SLUDGE

POSTER N. 149

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